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SPECIFICATION

PHASE SHIFTER CAPABLE OF MINIATURIZING AND METHOD OF MANUFACTURING THE SAME

TECHNICAL FIELD

The present invention relates to a phase shifter for switching passing phase of a high-frequency signal with ON/OFF control of a switching element, and, in particular, to a phase shifter, in which a micro-machine switch is used as a switching element.

BACKGROUND OF THE INVENTION

Recently, the possibility of use of micro-machine switches for switching elements used in phase shifters has been indicated. The micro-machine switches are finely machined switching elements. The micro-machine switches are featured in less loss, low cost and small electric power consumption as compared with other elements. This kind of micro-machine switch is disclosed in, for example, Japanese Patent Laid-Open No. 17300/1997.

Fig. 1 is a plan view showing a phase shifter making use of a micro-machine switch described in the above-mentioned Japanese Patent Publication. In addition, a wavelength of a high-frequency signal RF transmitting through a main line 201 is assumed to be λ. The phase shifter shown in Fig. 1 is a low deadline type phase shifter. More specifically, the main line 201 connects thereto two stubs 202a, 202b, which are opened at tip ends thereof and spaced away $\lambda/4$ from each other. Further, other stubs 203a, 203a with tip ends opened are arranged to be spaced from the stubs 202a, 202b. A micro-machine switch 209a having a contact 215 is arranged between the stubs 202a, 202b. Also, a

micro-machine switch 209b having a contact 215 is arranged between the stubs 202b, 203b.

The micro-machine switches 209a, 209b are put in OFF position, only the stubs 202a, 202b are loaded on the main line 201. Meanwhile, when the micro-machine switches 209a, 209b are put in ON position, the stubs 203a, 203b are further loaded on the main line 201 through the contact 215 of the micro-machine switches 209a, 209b. Accordingly, the stubs loaded on the main line 201 can be changed in electric length by making ON/OFF control on the micro-machine switches 209a, 209b.

Susceptance on a side of the stubs from the main line 201 varies depending upon the electric length of the stubs being loaded. Meanwhile, passing phase of the main line 201 varies in accordance with such susceptance. Accordingly, the high-frequency signal RF transmitting through the main line 201 can be switched over in passing phase by making ON/OFF control on the micro-machine switches 209a, 209b.

With reference to Figs. 2 and 3, an explanation will be given below to a constitution of and an operation of the micro-machine switch 209b shown in Fig. 1. Fig. 2 is a plan view showing the micro-machine switch 209b in enlarged scale. Figs. 3(A) to (C) are cross sectional views of the micro-machine switch 209b, Fig. 3(A) being a cross sectional view taken along the line C-C' in Fig. 2, Fig. 3(B) being a cross sectional view taken along the line D-D' in Fig. 2, and Fig. 3(C) being a cross sectional view taken along the line E-E' in Fig. 2.

The stubs 202b, 203b are formed on a substrate 210 in a manner to provide a slight gap therebetween. A lower electrode 211 is formed on the substrate 210 in a position spaced from the stubs 202b, 203b. Also, a post 212 is formed on the substrate 210 in a position on an extension of a line segment connecting the gap between the stubs 202b, 203b to the lower electrode 211.

A base portion of an arm 213 is fixed to a top surface of the post 212. The arm 213 extends from the top surface of the post 212 to a region above the gap between the stubs 202b, 203b through a region above the lower electrode 211. The arm 213 is formed from an insulating material. An upper electrode 214 is formed on an upper surface of the arm 213. The upper electrode 214 extends from a region above the post 212 to a region above the lower electrode 211. A contact 215 is formed on an underside of a tip end of the arm 213. The contact 215 is formed to extend from a region above an end of the stub 202b to bridge the gap to further extend to a region above an end of the stub 203b.

Further, a control signal line 204 is connected to the lower electrode 211. A control signal is applied to the lower electrode 211 from the control signal line 204. The control signal serves to make ON/OFF control of the micro-machine switch 209b for switching of connection of the stubs 202b, 203b.

It is assumed that voltage is applied to the lower electrode 211 as the control signal. In this case, if, for example, positive voltage is applied to the lower electrode 211, positive charges are generated on a surface of the lower electrode 211 and electrostatic induction causes negative charges to be generated on an underside of the upper electrode 214, which faces the lower electrode 211. As a result, attractive forces between the both electrodes cause the upper electrode 214 to be drawn toward the lower electrode 211. Thereby, the arm 213 bends and the contact 215 displace downward. And when the contact 215 comes into contact with both the stubs 202b, 203b, the stubs 202b, 203b connect to each other via the contact 215 in high-frequency fashion.

Meanwhile, when application of positive voltage on the lower electrode 211 is stopped, attractive forces disappear, so that restoring forces of the arm 213 returns the contact 215 to its original position.

Thereby, there is produced an opened state between the stubs 202b, 203b.

In addition, the micro-machine switch 209a shown in Fig. 1 is also constituted and operates in the same manner as the micro-machine switch 209b.

The micro-machine switch 209b shown in Fig. 1 necessitates the post 212 and the arm 213 for supporting of the contact 215, in addition to the contact 215 for connecting/opening between the stubs 202b, 203b. Also, the lower electrode 211 and the upper electrode 214 are further needed to control displacement of the contact 215. Therefore, the micro-machine switch 209b is large and complex in three-dimensional structure. The same is the case with the micro-machine switch 209a.

When such micro-machine switches 209a, 209b are used in a phase shifter, there is caused a problem that arrangement of the micro-machine switches 209a, 209b requires a large area to lead to large-sizing of the entire phase shifter. Also, manufacture of the micro-machine switches 209a, 209b having a complex construction necessitates many processes, and so the manufacturing processes for phase shifters become complex.

Therefore, an object of the present invention is to miniaturize a phase shifter, which makes use of micro-machine switches as a switching element.

Another object of the present invention is to simplify the construction of a phase shifter, which makes use of micro-machine switches as a switching element.

DISCLOSURE OF THE INVENTION

A phase shifter according to the present invention switches passing phase of a high-frequency signal by means of ON/OFF control of micro-machine switches.

A micro-machine switch according to a first example of the present invention comprises first and second distributed constant lines arranged on a substrate to be spaced from each other, a first control signal line connected electrically to the first or second distributed constant line for application of a first control signal composed of a binary change in voltage. The micro-machine switch also comprises a cantilever, one end of which is fixed to one of the first and second distributed constant lines and the other end of which is formed to be capable of coming toward and away from the other of the first and second distributed constant lines, the cantilever comprising an electrically conductive member. The micro-machine switch further comprises a first insulating section formed in a region where the other of the first and second distributed constant lines faces the cantilever, and a second insulating section for keeping a voltage value of the first control signal together with the first insulating section.

The cantilever unites the function as a movable contact and the function as a support for the movable contact. Accordingly, the cantilever corresponds to the contact 215, the arm 213 and the post 212 of a conventional micro-machine switch in terms of function, and the former can be formed to be small as compared with the latter and is simpler than the latter.

Also, the first control signal is applied to the first or second distributed constant line to control an action of the cantilever, so that the lower electrode 211 and the upper electrode 214, which have been conventionally necessary, are made unnecessary. In this regard, the micro-machine switch can be made small in size and simple in construction.

On the other hand, it is essential in the invention to provide a first insulating section for capacitive coupling and a second insulating section for holding of control voltage. However, it is possible according to the

present invention to make small-sized a phase shifter making use of the micro-machine switch and to simplify the phase shifter simple in construction.

Also, a phase shifter according to a second example of the present invention comprises a main line, through which a high-frequency signal is transmitted, and a first distributed constant line connected to the main line and opened at a tip end thereof. The phase shifter also comprises a second distributed constant line arranged to be spaced from the tip end of the first distributed constant line and opened at a tip end thereof. The phase shifter further comprises a cantilever, one end of which is fixed to one of the first and second distributed constant lines and the other end of which is formed to be capable of coming toward and away from the other of the first and second distributed constant lines, the cantilever comprising an electrically conductive member. The phase shifter further comprises a first control signal line connected electrically to the first or second distributed constant line and for applying of a first control signal composed of a binary change in voltage, a first insulating section formed in a region where the other of the first and second distributed constant lines faces the cantilever, and a second insulating section for keeping a voltage value of the first control signal together with the first insulating section.

A phase shifter according to a third example of the present invention comprises a main line, through which a high-frequency signal is transmitted, a first distributed constant line connected to the main line and opened at a tip end thereof, and a grounding arranged to be spaced from the tip end of the first distributed constant line. The phase shifter also comprises a cantilever, one end of which is fixed to one of the first and second distributed constant lines and the other end of which is formed to be capable of coming toward and away from the other of the first and second distributed constant lines, the cantilever comprising an electrically

conductive member. The phase shifter further comprises a first control signal line connected electrically to the first or second distributed constant line and for applying of a first control signal composed of a binary change in voltage, a first insulating section formed in a region where the other of the first and second distributed constant lines faces the cantilever, and a second insulating section for keeping a voltage value of the first control signal together with the first insulating section.

In accordance with the first to third examples, a low deadline type phase shifter can be constituted. In the case where a low deadline type phase shifter is to be constituted, the second insulating section is constituted by two capacitors formed midway the main line, and both the first and second distributed constant lines and the first control signal line are enabled to be connected electrically to the main line between the two capacitors.

Alternatively, the first control signal line may be connected electrically to the second distributed constant line, and the second insulating section may be constituted by the open end of the second distributed constant line.

A phase shifter according to a fourth example of the present invention includes a first distributed constant line with a cut part, two second distributed constant lines having different electric length, and a micro-machine switch for switching the second distributed constant lines, which short-circuits the cut part of the first distributed constant line to vary passing phase of a high-frequency signal. The micro-machine switch comprises cantilevers provided every second distributed constant line, one ends of the cantilevers being fixed to one of the first and second distributed constant lines and the other ends of the cantilevers being formed to be capable of coming toward and away from the other of the first and second distributed constant lines, the cantilevers comprising

electrically conductive members. The micro-machine switch also comprises a second control signal line connected electrically to one of the second distributed constant lines for application of a second control signal composed of a binary change in voltage, and a third control signal line connected electrically to the other of the second distributed constant lines for application of a third control signal complementary to the second control signal. The micro-machine switch further comprises first insulating sections, respectively, formed in regions where the other of the first and second distributed constant lines faces the cantilevers, and a second insulating section for keeping a voltage value of the second and third control signals together with the first insulating sections. In the micro-machine switch, the second and third control signal lines constitute a first control signal line.

A phase shifter according to a fifth example of the present invention includes a first distributed constant line with a cut part, two second distributed constant lines having different electric length, and a micro-machine switch for switching the second distributed constant lines, which short-circuit the cut part of the first distributed constant line to vary-passing phase of a high-frequency signal. The micro-machine switch comprises cantilevers provided every second distributed constant line, one ends of the cantilevers being fixed to one of the first and second distributed constant lines and the other ends of the cantilevers being formed to be capable of coming toward and away from the other of the first and second distributed constant lines, the cantilevers comprising electrically conductive members. The micro-machine switch also comprises a first control signal line connected electrically to the first distributed constant line for application of a first control signal composed of a binary change in voltage. The micro-machine switch further comprises first insulating sections, respectively, formed in regions where

the other of the first and second distributed constant lines faces the cantilevers, and a second insulating section for keeping a voltage value of the first control signal together with the first insulating sections. In the micro-machine switch, constant voltages, respectively, equivalent to respective voltage values of two states of the first control signal are applied to the respective second distributed constant lines.

With the above-mentioned constitution, it is possible to constitute a switched-line type phase shifter. In these cases, the cantilevers, respectively, may be provided on both ends of the respective second distributed constant lines.

In the above-mentioned cases, a first constituent example of the first insulating section is an insulating film formed on at least one of an upper surface of the other of the first and second distributed constant lines and an underside of the cantilever. Thereby, the first insulating section can be simply constituted.

Also, the phase shifter described above may comprise a first high-frequency signal blocking unit connected to the first control signal line to block passage of the high-frequency signal.

In this case, a first constituent example of the first high-frequency signal blocking unit comprises a high-impedance line connected at one end thereof to that one of the first and second distributed constant lines, to which the first control signal line is connected electrically, and having an electric length of about one fourth as long as a wavelength of the high-frequency signal and a greater characteristics impedance than those of the first and second distributed constant lines. The first constituent example comprises a low-impedance line connected at one end thereof to the other of the high-impedance line and opened at the other thereof, and having an electric length of about one fourth as long as the wavelength of the high-frequency signal and a smaller characteristics impedance than

that of the high-impedance line. In this case, the first control signal line is connected to the other end of the high-impedance line.

A second constituent example of the first high-frequency signal blocking unit comprises a high-impedance line connected at one end thereof to that one of the first and second distributed constant lines, to which the first control signal line is connected electrically, and having an electric length of about one fourth as long as a wavelength of the high-frequency signal and a greater characteristics impedance than those of the first and second distributed constant lines. The second constituent example comprises a capacitor with one of electrodes connected to the other of the high-impedance line and the other of electrodes connected to a grounding. In this case, the first control signal line is connected to the other end of the high-impedance line.

A third constituent example of the first high-frequency signal blocking unit comprises an inductance element.

A fourth constituent example of the first high-frequency signal blocking unit comprises a resistor element having a sufficiently greater impedance than those of the first and second distributed constant lines. In this case, the resistor element may be insertion connected in series to the first control signal line. Alternatively, the resistor element may be connected at one end thereof to the first control signal line and opened at the other end thereof.

In this manner, leak of a high-frequency signal to the first control signal line can be prevented by providing the first high-frequency signal blocking unit on the first control signal line.

Also, the phase shifter described above may comprise a fourth control signal line connected electrically to that one of the first and second distributed constant lines, to which the first control signal line is not connected electrically, and for charging and discharging electric charges

generated by electrostatic induction.

In this manner, the electric charges generated by electrostatic induction is charged and discharged through the fourth control signal line whereby the micro-machine switch is made stable in switching action and increased in switching speed.

Also, the phase shifter described above may comprise a fourth control signal line connected electrically to that one of the first and second distributed constant lines, to which the first control signal line is not connected electrically, and for applying of constant voltage having a reverse polarity to that of the first control signal, and a third insulating section formed on that one of the first and second distributed constant lines, to which the fourth control signal line is connected electrically, and for keeping a voltage value of the constant voltage applied from the fourth control signal line together with the first insulating section.

In this manner, if a predetermined voltage is beforehand applied to that distributed constant line, to which the first control signal is not applied, the first control signal can be correspondingly made small in voltage level.

The phase shifter described above may comprise a second high-frequency signal blocking unit connected to the fourth control signal line to block passage of the high-frequency signal. In this case, a first constituent example of the second high-frequency signal blocking unit comprises a high-impedance line connected at one end thereof to that one of the first and second distributed constant lines, to which the first control signal line is not connected electrically, and having an electric length of about one fourth as long as a wavelength of the high-frequency signal and a greater characteristics impedance than those of the first and second distributed constant lines. The first constituent example also comprises a low-impedance line connected at one end thereof to the other end of the high-impedance line and opened at the other end thereof, and having an

electric length of about one fourth as long as the wavelength of the high-frequency signal and a smaller characteristics impedance than that of the high-impedance line. In this case, the fourth control signal line is connected to the other end of the high-impedance line.

A second constituent example of the second high-frequency signal blocking unit comprises a high-impedance line connected at one end thereof to that one of the first and second distributed constant lines, to which the first control signal line is not connected electrically, and having an electric length of about one fourth as long as a wavelength of the high-frequency signal and a greater characteristics impedance than those of the first and second distributed constant lines. The second constituent example also comprises a capacitor with one of electrodes connected to the other of the high-impedance line and the other of electrodes connected to a grounding. In this case, the fourth control signal line is connected to the other end of the high-impedance line.

A third constituent example of the second high-frequency signal blocking unit comprises an inductance element.

A fourth constituent example of the second high-frequency signal blocking unit comprises a resistor element having a sufficiently greater impedance than those of the first and second distributed constant lines. In this case, the resistor element may be insertion connected in series to the fourth control signal line. Alternatively, the resistor element may be connected at one end thereof to the fourth control signal line and opened at the other end thereof.

Leak of a high-frequency signal to the fourth control signal line can be prevented by providing the second high-frequency signal blocking unit on the fourth control signal line as described above.

Also, the phase shifter described above comprises first and second high-impedance lines connected at one ends thereof to the first and

second distributed constant lines, and having an electric length of about one fourth as long as a wavelength of the high-frequency signal and a greater characteristics impedance than those of the first and second distributed constant lines. The phase shifter also comprises a capacitor with one of electrodes connected to the other of the first high-impedance line and the other of electrodes connected to the other of the second high-impedance line. In this case, the first high-impedance line may be connected at the other end thereof to the first control signal line, and the second high-impedance line may be connected at the other end thereof to a grounding.

With this constitution, the first high-frequency signal blocking unit is constituted by the first high-impedance line, the capacitor and the grounding. Also, the second high-frequency signal blocking unit is constituted by connecting the second high-impedance line to the grounding.

A method of manufacturing a phase shifter, according to the present invention comprises a first step of forming on a substrate a portion of a main line, a first distributed constant line connected to the portion of the main line, a second distributed constant line, an end of which is spaced from an end of the first distributed constant line, and a control signal line connected to the portion of the main line. The method also comprises a second step of forming a sacrificing layer in a region extending from a gap between the first and second distributed constant lines to the end of the first or second distributed constant line. The method further comprises a third step of forming a first insulating film on that portion of the sacrificing layer, which faces the end of the first or second distributed constant line, and a second insulating film on both ends of the portion of the main line. The method further comprises a fourth step of forming a cantilever of metal on an area extending from that end of

the second or first distributed constant line, on which the sacrificing layer is not formed, to the first insulating film on the sacrificing layer, and at the same time forming other portions of the main line on the second insulating film and the substrate; and a fifth step of removing the sacrificing layer.

Thereby, the micro-machine switch described above can be manufactured in a less number of processes.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view showing the case where a conventional micro-machine switch is used in a well-known phase shifter;

Fig. 2 is a plan view showing in enlarged scale the conventional micro-machine switch shown in Fig. 1;

Figs. 3(A) to (C) are cross sectional views of the conventional micro-machine switch shown in Fig. 1;

Fig. 4 is a circuit diagram showing a phase shifter according to a first embodiment of the present invention;

Fig. 5 is a plan view showing the phase shifter shown in Fig. 4;

Figs. 6(A) and (B) are cross sectional views of the phase shifter shown in Fig. 4;

Fig. 7 is a circuit diagram showing a modified configuration of the phase shifter shown in Fig. 4;

Fig. 8 is a cross sectional view showing a modified configuration of a first insulating section shown in Figs. 6(A) and (B);

Fig. 9 is a cross sectional view showing a modified configuration of a cantilever shown in Figs. 6(A) and (B);

Figs. 10(A) to 10(E) are cross sectional views illustrating main processes when the phase shifter shown in Fig. 4 is manufactured;

Figs. 11(A) to 11(D) are cross sectional views illustrating processes subsequent to Fig. 10(E);

Fig. 12 is a circuit diagram showing a phase shifter according to a second embodiment of the present invention;

Fig. 13 is a plan view showing the phase shifter shown in Fig. 12;

Fig. 14 is a circuit diagram showing a phase shifter according to a third embodiment of the present invention;

Fig. 15 is a circuit diagram showing a first constituent example of the first high-frequency signal blocking unit shown in Fig. 14;

Fig. 16 is a plan view showing the first high-frequency signal blocking unit shown in Fig. 14;

Fig. 17 is a circuit diagram showing a second constituent example of the first high-frequency signal blocking unit;

Fig. 18 is a plan view showing the first high-frequency signal blocking unit shown in Fig. 17;

Fig. 19 is a circuit diagram showing a third constituent example of the first high-frequency signal blocking unit;

Fig. 20 is a plan view showing a concrete example of the first high-frequency signal blocking unit shown in Fig. 19;

Fig. 21 is a plan view showing another concrete example of the first high-frequency signal blocking unit shown in Fig. 19;

Fig. 22 is a circuit diagram showing a fourth constituent example of the first high-frequency signal blocking unit;

Fig. 23 is a plan view showing the first high-frequency signal blocking unit shown in Fig. 22;

Fig. 24 is a circuit diagram showing a modified configuration of the first high-frequency signal blocking unit shown in Fig. 22;

Fig. 25 is a plan view showing the first high-frequency signal blocking unit shown in Fig. 24;

Fig. 26 is a circuit diagram showing a constitution of a phase shifter according to a fourth embodiment of the present invention;

Fig. 27 is a plan view showing the phase shifter shown in Fig. 26;

Fig. 28 is a circuit diagram showing a constitution of a phase shifter according to a fifth embodiment of the present invention;

Fig. 29 is a circuit diagram showing a constitution of a phase shifter when both the first and second high-frequency signal blocking units are constituted in the same manner as a filter 40 is;

Fig. 30 is a plan view showing the phase shifter shown in Fig. 29;

Fig. 31 is a circuit diagram showing a constitution of a phase shifter according to a sixth embodiment of the present invention;

Fig. 32 is a circuit diagram showing a modified configuration of the phase shifter shown in Fig. 31;

Fig. 33 is a plan view showing a constitution of a phase shifter according to a seventh embodiment of the present invention;

Fig. 34 is a plan view showing a constitution of a phase shifter according to an eighth embodiment of the present invention;

Fig. 35 is a plan view showing another constituent example of the phase shifter shown in Fig. 34;

Fig. 36 is a plan view showing a constituent example when two phase shifters are cascade-connected;

Fig. 37 is a plan view showing another constituent example when two phase shifters are cascade-connected;

Fig. 38 is a plan view showing an arrangement, in which a phase shifter having been subjected to the chip processing is mounted on a substrate to form the phase shifter shown in Figs. 15 and 16;

Fig. 39 is a plan view showing another example of the arrangement shown in Fig. 38;

Fig. 40 is a plan view showing another constituent example of the first insulating section;

Figs. 41(A) and 41(B) are cross sectional views showing the first insulating section shown in Fig. 40 at the time of OFF.

Figs. 42(A) and 42(B) are cross sectional views showing the first insulating section shown in Fig. 40 at the time of ON.

BEST MODE FOR CARRYING OUT THE INVENTION

(FIRST EMBODIMENT)

With reference to Figs. 4 and 5, an explanation will be given to a phase shifter according to a first embodiment of the present invention. Fig. 4 is a circuit diagram showing the phase shifter according to the first embodiment of the present invention, and Fig. 5 is a plan view showing the phase shifter. Fig. 6(A) is a cross sectional view taken along the line IIA-IIA' in Fig. 5, and Fig. 6(B) is an enlarged, cross sectional view showing a portion IIB in Fig. 6(A). Fig. 7 is a circuit diagram showing a modification of the phase shifter shown in Fig. 4. Also, Fig. 8 is a cross sectional view showing a modified configuration of a first insulating section shown in Figs. 6(A) and 6(B). Also, Fig. 9 is a cross sectional view showing a modified configuration of a cantilever shown in Fig. 5.

As shown in Figs. 4 and 5, a main line 1, through which a high-frequency signal RF is transmitted, is composed of lines 1a, 1b and 1C. Here, the line 1b is formed at both ends thereof with capacitors 15a, 15b, respectively. The lines 1a and 1b are connected to each other through the capacitor 15a in high-frequency fashion, and the lines 1b and 1c are connected to each other through the capacitor 15b in high-frequency fashion.

The capacitor 15a is formed by overlapping the lines 1a and 1b vertically with an insulating film 16a of SiO_2 or the like interposed therebetween as shown in, for example, Fig. 5. The capacitor 15b is similarly formed by interposing an insulating film 16b between the lines 1b and 1c.

The capacitors 15a, 15b also function as a second insulating section for insulating other microwave circuit (not shown) connected to the lines 1a, 1c from the line 1b in direct current or low frequency fashion. Accordingly, coupling capacitors contained in the other microwave circuit may be utilized as a second insulating section. The second insulating section as well as a first insulating section described later also has the function of keeping voltage values of stubs 2a, 2b at a voltage value of a control signal S described later at the time of connection (ON) of the stubs 2a, 3a.

In addition, as shown in Fig. 7, another microwave circuit 91 may be connected midway the line 1b.

As shown in Fig. 4, two stubs 2a and 2b (first distributed constant line) with tip ends thereof opened are connected to the line 1b, which is a part of the main line 1, with $\lambda/4$ spaced from each other. Here, λ is a wavelength of a high-frequency signal RF. Further, other two stubs 3a and 3b (second distributed constant line), respectively, with tip ends thereof opened are arranged to be spaced away from the tip ends of the stubs 2a and 2b.

Here, the stubs 2a and 2b have an electrical length L1, and the stubs 3a and 3b have an electrical length L2 with a gap G between the stubs 2a and 2b and the stubs 3a and 3b.

The main line 1 and the stubs 2a, 2b, 3a and 3b described above are formed from a microstrip line of metal, for example, aluminum to be disposed on a substrate 10. In addition, the main line 1 and the stubs 2a, 2b, 3a and 3b may be formed from other distributed constant lines such as coplanar lines, triplate lines, slot lines or the like.

Also, the substrate 10 is formed by the use of, for example, a dielectric substrate such as glass substrate or semiconductor substrate such as Si, Ga, As or the like.

A post 12 including an electrically conductive member such as aluminum is formed on an end (end toward the stub 2a) of the stub 3a. A base portion of an arm 13 is fixed to a top surface of the post 12. The arm 13 extends above a tip end of the stub 2a from the top surface of the post 12. The arm 13 is formed from materials, which have electroconductivity and are returned to an original shape even when once curved. The arm 13 is formed from, for example, Al, Au, Cu or the like. The arm 13 may also be formed from silicone, which has electroconductivity due to diffusion of boron. In the following, the post 12 and the arm 13 are referred to as a cantilever 11a together.

As described later with reference to Fig. 9 and Figs. 10(A) to 10(E), the post 12 and the arm 13 may be a single member of the same material to constitute the cantilever 11a. Conversely, as shown in Figs. 6(A) and 6(B), the post 12 and the arm 13 must not be necessarily made of the same material. Each of the post 12 and the arm 13 must not be necessarily made of a single material but may be made of a plurality of materials. Also, in this case, all of the plurality of materials must not be electrically conductive but may partially contain an insulating material. For example, the arm 13 may be of two layered construction, in which a conductive material such as Al and an insulating material such as SiO_2 are laminated on one another because of strength. Also, the post 12 may contain an insulating material to an extent that transmission of the high-frequency signal RF is not obstructed.

As shown in Figs. 6(A) and 6(B), an underside of a tip end of the arm 13, that is, a portion thereof opposed to the stub 2a is formed with an insulating film 14 of SiO_2 or the like, which serves as the first insulating section. The arm 13 is given a predetermined height by the post 12, and the insulating film 14 formed on the arm 13 is usually (at the time of OFF) spaced away from the stub 2a. Conversely, the height of the post 13 is

determined so as to usually have the insulating film 14 and the stub 2a spaced away from each other.

The first insulating section together with the capacitors 15a, 15b serves to keep a voltage value of the stub 2a at a voltage value of the control signal S described later at the time of connection (ON) of the stubs 2a, 3a. Accordingly, an insulating film 14a, shown in Fig. 8, formed on the top surface of the tip end of the stub 2a may be used as the first insulating section. Also, the insulating films 14 and 14a may combine to form the first insulating section.

In addition, there is no need of the voltage value of the stub 2a completely corresponding to a voltage value of the control signal S, and the voltage value of the stub 2a suffices to be kept to such an extent that the cantilever 11a can act based on the control signal S. Also, while a side of the cantilever 11a toward the stub 3a is fixed in Figs. 6(A) and 6(B), a side of the cantilever 11a' toward the stub 2a may be conversely fixed as shown in Fig. 9. In any way, the cantilevers 11a, 11a' suffice to be constructed such that one ends of the cantilevers are fixed to one of the stubs 2a, 3a and the other ends of the cantilevers can come toward and away from the other of the stubs 2a, 3a. As shown in Fig. 4, a cantilever 11b and the insulating films 14 and 14a are formed on a side of the stubs 2b, 3b in the same manner as on a side of the stubs 2a, 3a.

A control device 5 is connected to the line 1b, which constitutes a part of the main line 1, through a first control signal line 4. The control device 5 acts to output the control signal (first control signal) S composed of a binary change in voltage. As described later, a state of connection for the stubs 2a, 2b and the stubs 3a, 3b is switched over on the basis of the control signal S.

In addition, the first control signal line 4 may not be connected directly to the line 1b. For example, the first control signal line 4 suffices

to be connected electrically to the line 1b as shown in Figs. 15 and 16 and Figs. 17 and 18.

In the above manner, a low deadline type phase shifter is constituted.

An explanation will be then given to an operation of a micro-machine switch, which functions as a switching element in the phase shifter shown in Fig. 4. Here, for the sake of convenience, the control signal S is ON/OFF of positive voltage. In addition, an explanation will be given with respect to the stubs 2a, 3a, and it goes without saying that the same operation is performed on the stubs 2b, 3b.

As described above, since the insulating film 14 at the tip end of the arm 13 is spaced away from the stub 2a at the usual time, high-frequency connection of the stubs 2a, 3a is opened. At this time, if a positive voltage is applied to the line 1b through the first control signal line 4 from the control device 5, positive charges are generated on a surface of the stub 2a connected to the line 1b. Thereby, electrostatic induction causes negative charges to appear on an underside of the tip end of the arm 13 opposed to the stub 2a, and an attracting force is generated between the stub 2a and the arm 13. Such attracting force causes the arm 13 to bend toward the substrate 10, and when the insulating film 14 formed on the tip end of the arm 13 comes into contact with the stub 2a, capacitive coupling connects the stub 2a and the stub 3a to each other in high-frequency fashion.

At this time, the capacitors 15a, 15b insulate the line 1b from the lines 1a, 1c in direct-current or low-frequency fashion. Further, the line 1b is insulated from another microwave circuit (not shown) in direct-current or low-frequency fashion. Hence, the control signal S imparted to the line 1b will not leak to another microwave circuit, and so will not affect another microwave circuit adversely. At the same time, voltage values of

the line 1b and the stub 2a, which are surrounded by the capacitors 15a, 15b and the insulating film 14, are maintained.

Meanwhile, when application of positive voltage to the line 1b is stopped, the attracting force between the stub 2a and the arm 13 disappears. Hence, the arm 13 returns to its original configuration, so that the insulating film 14 is separated from the stub 2a. Thereby, high-frequency connection between the stubs 2a, 3a is released.

Referring to Fig. 6(B), an explanation will be then given to an example of dimensions of the respective parts of the micro-machine switch. Here, the arm 13 is formed of aluminum, and voltage of 40 V is applied as the control signal S.

First, to obtain a desired spring constant in view of strength of the arm 13, a thickness t of the arm 13 is determined to be around 0. 5 μm. Also, a height H between a top of the stub 2a and the insulating film 14 formed on the arm 13 is around 5 μm at normal times. Further, facing areas of the stub 2a and of the arm 13 are around 0.01 mm^2.

Various dimensions are set in the above manner, and then it becomes possible to realize a micro-machine switch, which operates in the above-mentioned manner. In addition, the dimensions of the respective portions referred to here are only exemplary, and the respective portions are not limited to such dimensions.

An explanation will be then given to a principle of operation of the entire phase shifter shown in Fig. 4. When the control signal S outputted from the control device 5 is OFF, and high-frequency connections between the stubs 2a, 3a and between the stubs 2b, 3b are released, only the stubs 2a, 2b having an electrical length L1 are loaded on the main line 1 composed of the stubs 1a to 1c.

Meanwhile, when the control signal S is made ON, and high-frequency connections between the stubs 2a, 3a and between the stubs

2b, 3b are established, the stubs 3a, 3b are further loaded on the main line 1 through the cantilevers 11a, 11b. At this time, the stubs loaded on the main line 1 have an electrical length (L1 + L2 + G). In this manner, ON/OFF of the control signal S enables changing an electrical length of the stubs loaded on the main line 1.

Susceptance of the stubs as viewed from the main line 1 varies in accordance with an electrical length of the stubs loaded. Meanwhile, the main line 1 varies in passing phase due to such susceptance. Accordingly, the control signal S is made ON/OFF to control high-frequency connections between the stubs 2a, 3a and between the stubs 2b, 3b, whereby the high-frequency signal RF transmitting through the main line 1 can be switched in phase-shift amount.

In addition, although the capacitors 15a, 15b are incorporated midway the main line 1, transmission of the high-frequency signal RF is in no way hindered provided that the capacitors are made adequately large in capacitance.

An explanation will be then given to a method of manufacturing the phase shifter shown in Fig. 4. Figs. 10(A) to 10(E) and Figs. 11(A) to 11(D) are cross sectional views showing main processes when the phase shifter according to the embodiment is manufactured. In these figures, a cross section as viewed in the line IIA-IIA' in Fig. 5 is shown.

First, photoresist is applied to the substrate 10. The photoresist is subjected to patterning with the known photolithographic technique to form a resist pattern 21 having a groove 21a in a predetermined position. In addition, Fig. 10(A) shows the groove 21a where the stubs 2a, 3a and the line 1b are formed in the subsequent process while a groove is simultaneously formed on a portion where the stubs 2b, 3b and the first control signal line 4 are formed.

As shown in Fig. 10(B), a metal film 22 of Al is formed over the entire substrate 10 with the sputtering method. Subsequently, the metal film 22 on the resist pattern 21 is selectively removed (lifted off) by removing the resist pattern 21 so that the stubs 2a, 3a and the line 1b are formed on the substrate 10 as shown in Fig. 10(C). Incidentally, removal of the resist pattern 21 is carried out with a method, in which the resist pattern 21 is dissolved in an organic solvent. Although not shown, the stubs 2b, 3b and the first control signal line 4 are simultaneously formed.

As shown in Fig. 10(D), polyimide having photosensitivity is applied and dried to form a sacrificing layer 23 having a film thickness in the order of 5 to 6 μm over the entire substrate 10. Subsequently, the known photolithographic technique is used to perform patterning on the sacrificing layer 23 as shown in Fig. 10(E). Thereby, unnecessary portions are removed while leaving the sacrificing layer 23 in a region (i.e. region where the arm 13 shown in Fig. 1 is formed) extending from a gap between the stubs 2a, 3a to a tip end of the stub 2a (an end toward the stub 3a). In addition, the sacrificing layer 23 is left in an area except an end of the stub 3a in Fig. 10(E). Also, although not shown, patterning is similarly performed on the sacrificing layer on a side of the stubs 2b, 3b. Subsequently, heating treatment is performed at 200 to 300℃ to cure the sacrificing layer 23 as left.

As shown in Fig. 11(A), SiO_2 is deposited over the entire substrate 10 with a method, such as a CVD method or a sputtering method, to form an insulating film 24 having a film thickness in the order of 0.01 to 0.3 μm. Subsequently, the known photolithographic technique and etching technique are used to remove the insulating film 24 leaving predetermined portions thereof. In this manner, as shown in Fig. 11(B), an insulating film 14 (first insulating film) is formed on a portion of the sacrificing layer 23 opposed to the tip end of the stub 2a, and an insulating film 16a (second

insulating film) is formed on an end of the line 1b, which defines a connection between it and the stub 2a. Although not shown, an insulating film 14 (first insulating film) and an insulating film 16b (second insulating film) are similarly formed on the side of the stubs 2b, 3b. In addition, photoresist as used is removed with an alkali solvent.

As shown in Fig. 11(C), the cantilever 11a made of Al is formed in an area extending an end of the stub 3a to the insulating film 14 on the sacrificing layer 23, and at the same time the line 1a made of Al is formed on the substrate 10 to extend from the insulating film 16a. Formation of these parts is carried out with the use of a lift-off method. Also, although not shown, the cantilever 11b and the line 1c are also at the same time formed likewise.

Finally, the phase shifter is finished by selectively removing only the sacrificing layer 23 as shown in Fig. 11(D) with a dry etching method, in which plasma of oxygen gas is used.

In the above description, a method, in which the post 12 and the arm 13, which constitute the cantilevers 11a, 11b, are formed in the same process, but the post 12 and the arm 13 may be formed in separate processes.

Here, the phase shifter shown in Fig. 4 and the conventional phase shifter shown in Fig. 1 are compared with each other, centering around the constitution of a micro-machine switch. First, the cantilevers 11a, 11b of the micro-machine switch shown in Fig. 4 unite the function as a movable contact and the function as a support for the movable contact. Accordingly, the cantilevers 11a, 11b correspond to the contact 215, the arm 213 and the post 212 of the micro-machine switch shown in Fig. 1 in terms of function, and the former can be formed to be small as compared with the latter and is simpler than the latter.

Also, while the cantilevers 11a, 11b are constituted by the post 12 and the arm 13, formation of the cantilevers 11a, 11b is very easy since the post 12 and the arm 13 can be formed in the same process as shown in Fig. 11(C).

Also, with the micro-machine switch shown in Fig. 4, the control signal S is applied to the line 1b of the main line 1 to control actions of the cantilevers 11a, 11b. Therefore, the lower electrode 211 and the upper electrode 214, which are required in the phase shifter shown in Fig. 1, are made unnecessary. In this regard, the micro-machine switch according to the present invention can be made small in size and simple in construction.

Meanwhile, with the micro-machine switch shown in Fig. 4, the insulating films 14, 16a, 16b are required for maintaining voltage value of the control signal S. However, in the case where conventional micro-machine switches are of capacitive coupling type, it is necessary to form an insulating film on an underside of the contact 215. Also, as shown in Figs. 11(B) and 11(C), the insulating films 16a, 16b can be formed in the same process as the insulating film 14 is, and also the lines 1a, 1c, which constitute other part of the main line 1, can be formed in the same process as the cantilevers 11a, 11b are, so that the manufacturing process is not made complex.

As described above, it is possible according to the present invention to make a micro-machine switch small-sized and to simplify the switch simple in construction. Therefore, a phase shifter can be made as a whole small-sized as compared with the prior art and formed in less processes by using the micro-machine switch as a switching element.

(SECOND EMBODIMENT)

Figs. 12 and 13, respectively, are a circuit diagram and a plan view showing a phase shifter according to a second embodiment of the present

invention. In Figs. 12 and 13, the same elements as those in Figs. 4 and 5 are designated by the same reference numerals and an explanation of the elements are suitably omitted.

The phase shifter shown in Figs. 4 and 5 and the phase shifter shown in Figs. 12 and 13 are different from each other in position of connection of the first control signal line 4. More specifically, the first control signal line 4 is connected to the main line 1 in the phase shifter shown in Figs. 4 and 5. In contrast, the first control signal line 4 is connected to the stubs 3a and 3b in the phase shifter shown in Figs. 12 and 13.

The stubs 3a and 3b are opened at tip ends thereof and not connected to other microwave circuits. Therefore, with the phase shifter shown in Figs. 12 and 13, the open tip ends of the stubs 3a and 3b function as a second insulation without the need of provision of the capacitors 15a and 15b shown in Figs. 4 and 5. Accordingly, being constituted as shown in Figs. 12 and 13, the phase shifter becomes more simple in construction.

(THIRD EMBODIMENT)

Fig. 14 is a circuit diagram showing a constitution of a phase shifter according to a third embodiment of the present invention. In Fig. 14, the same elements as those in Fig. 4 are designated by the same reference numerals and an explanation of the elements are suitably omitted.

The phase shifter shown in Fig. 14 is constituted by connecting a first high-frequency signal blocking unit 6 to the first control signal line 4 of the phase shifter shown in Fig. 4. The first high-frequency signal blocking unit 6 acts to block passage of the high-frequency signal RF. Accordingly, the high-frequency signal RF transmitting through the main line 1 can be prevented from flowing into the control device 5 to reduce insertion loss of the phase shifter.

Also, with the phase shifter shown in Fig. 4, there is the possibility that electricity leaking from the first control signal line 4 couples with other microwave circuits, depending upon the manner of wiring of the first control signal line 4, to adversely affect the performance of the whole circuit or make responsible for resonance. However, a circuit, in which the phase shifter is used, can be improved in high-frequency characteristics since electromagnetic coupling of the first control signal line 4 with other microwave circuits can be prevented by connecting the first high-frequency signal blocking unit 6 to the first control signal line 4.

In addition, a similar effect can be obtained by connecting the first high-frequency signal blocking unit 6 to the first control signal line 4 in the phase shifter shown in Figs. 12 and 13.

Referring to Figs. 15 to 25, an explanation will be then given to constituent examples of the first high-frequency signal blocking unit 6 in Fig. 14. First, an explanation will be given to a first constituent example of the first high-frequency signal blocking unit 6. Figs. 15 and 16, respectively, are a circuit diagram and a plan view showing the first constituent example. The first constituent example of the first high-frequency signal blocking unit 6 is a filter 30 composed of a high-impedance $\lambda/4$ line 31 and a low-impedance $\lambda/4$ line 32. The high-impedance $\lambda/4$ line 31 has an electric length of about $\lambda/4$ (λ is a wavelength of the high-frequency signal RF) and a greater characteristics impedance than that of the main line 1. Also, the low-impedance $\lambda/4$ line 32 has an electric length of about $\lambda/4$ and a less characteristics impedance than that of the high-impedance $\lambda/4$ line 31.

It is desired that values of the characteristics impedances of these lines 31, 32 are such that when, for example, the main line 1 has generally a characteristic impedance of 50 Ω, the high-impedance $\lambda/4$ line 31 has a characteristic impedance of about 70 to 200 Ω and the low-impedance

$\lambda/4$ line 32 has a characteristic impedance of about 20 to 40 Ω.

The high-impedance $\lambda/4$ line 31 is connected at one end thereof to the line 1b, which is a part of the main line 1, and at the other end thereof to an end of the low-impedance $\lambda/4$ line 32. The low-impedance $\lambda/4$ line 32 is opened at the other end thereof. Further, connected to the other end (i.e. a connection 33 of the lines 31 and 32) of the high-impedance $\lambda/4$ line 31 is the first control signal line 4 of high-impedance. Accordingly, the first control signal line 4 is connected electrically to the line 1b via the high-impedance $\lambda/4$ line 31.

An explanation will be given below to a principle of operation of the filter 30. As described above, the low-impedance $\lambda/4$ line 32 is opened at the other end thereof. Therefore, impedance on a side of the low-impedance $\lambda/4$ line 32 as viewed from the connection 33 spaced $\lambda/4$ from such other end amounts to 0 Ω, which means in a state equivalent to high-frequency grounding at the connection 33. Accordingly, even when the first control signal line 4 is connected in parallel to the connection 33, impedance at the connection 33 remains 0 Ω to have no influence on the behavior of high frequency.

Further, since the line 1b is connected from the connection 33 via the high-impedance $\lambda/4$ line 32 having an electric length of $\lambda/4$, impedance on a side of the filter 30 from the line 1b becomes infinite (∞ Ω). Accordingly, high-frequency wave does not flow to the side of the filter 30 from the line 1b, so that it leads to a state, in which the filter 30 and the first control signal line 4 are not present in terms of high frequency. The constitution of the filter 30 described herein is generally called a bias tee, and blocks only a particular frequency band to act as a kind of band blocking filter.

An explanation will be then given to a second constituent example of the first high-frequency signal blocking unit 6. Figs. 17 and 18,

respectively, are a circuit diagram and a plan view showing the second constituent example. The second constituent example of the first high-frequency signal blocking unit 6 is a filter 40 composed of a high-impedance λ/4 line 41, a capacitor 42, and a grounding 43.

As shown in Fig. 17, the high-impedance λ/4 line 41 is connected at one end thereof to the line 1b, which is a part of the main line 1, and at the other end thereof to one of electrodes of the capacitor 42. Also, the other of the electrodes of the capacitor 42 is connected to the grounding 43. Further, the first control signal line 4 is connected to the one of the electrodes of the capacitor 42, to which the high-impedance λ/4 line 41 is connected. Accordingly, the first control signal line 4 is connected electrically to the line 1b via the high-impedance λ/4 line 41.

As shown in Fig. 18, the capacitor 42 can be composed of an electrode 44, which makes the above-mentioned the one of the electrodes, an electrode 43a, which makes the other of the electrodes and is grounded, and an insulating film 45 interposed between the electrodes 44, 43a. The high-impedance λ/4 line 41 has a high characteristic impedance and an electric length of about λ/4 (λ is a wavelength of the high-frequency signal RF). A value of the characteristic impedance of the high-impedance λ/4 line 41 is determined in the same manner as that of the high-impedance λ/4 line 31 in Figs. 15 and 16.

An explanation will be given below to a principle of operation of the filter 40. Since the capacitor 42 has an adequate capacitance, a connection of the high-impedance λ/4 line 41 and the capacitor 42 is put in a state equivalent to high-frequency grounding, and so impedance makes 0Ω. Accordingly, like the case shown in Figs. 15 and 16, even when the first control signal line 4 is further connected to the connection, there is no influence in terms of high frequency. Further, since the line 1b is connected from the capacitor 42 via the high-impedance λ/4 line 41

having an electric length of $\lambda/4$, impedance on a side of the filter 40 from the line 1b becomes infinite ($\infty\,\Omega$), that is, the high-frequency signal RF does not flow to the side of the filter 40 from the line 1b.

The filter 40 described herein is a kind of bias tee, and acts as a band blocking filter.

An explanation will be then given to a third constituent example of the first high-frequency signal blocking unit 6. Fig. 19 is a circuit diagram illustrating the third constituent example. Also, Figs. 20 and 21 are plan views showing a concrete example of the third constituent example.

The third constituent example of the first high-frequency signal blocking unit 6 is a filter 50 composed of an inductance element. It is possible to use, for example, a spiral inductor 51 shown in Fig. 20 or an underline inductor 52 shown in Fig. 21, for the filter 50.

Since these inductive circuit elements exhibit low impedance at DC to low frequency and a high impedance at high frequency, they act as a low-pass filter. However, cut-off frequency is set to be lower than the frequency of the high-frequency signal RF. In place of these distributed constant elements, lumped constant elements such as coils may be used in exterior connection. In addition, other types of filters such as filters, which are composed by cascade-connecting lines having different characteristic impedance in multi-stage, can be used as low-pass filters.

An explanation will be then given to a fourth constituent example of the first high-frequency signal blocking unit 6. Figs. 22 and 23, respectively, are a circuit diagram and a plan view showing the fourth constituent example. As shown in Fig. 22, as the first high-frequency signal blocking unit 6, a resistor element 61 is incorporated in series into the first control signal line 4 to enable blocking inflowing of the high-frequency signal RF. While a value of impedance of the resistor element 61 suffices to be equal to or more than two times as the characteristic

impedance of the main line 1, it is desirably set to substantially at least twenty times as the latter. More specifically, if the main line 1 has generally a characteristic impedance of 50Ω, impedance of the resistor element 61 is determined to be substantially equal to or more than 1 kΩ. In this manner, with impedance of the resistor element 61 being determined, impedance on the side of the first control signal line 4 from the main line 1 becomes large, so that leak of the high-frequency signal RF to the first control signal line 4 can be suppressed.

For formation of the resistor element 61, a method of forming thin film resistor elements with, for example, a vacuum deposition method or the sputtering method, and a method of utilizing semiconductor n layer or n+ layer can be made use of.

To prevent leak of the high-frequency signal RF to the first control signal line 4, addition of the filters 30, 40, 50 shown in Figs. 15 to 21 makes the whole size of the micro-machine switch increase, but the resistor element 61 shown in Figs. 22 and 23 is made use of to attain the above-mentioned purpose without an increase in the whole size.

In addition, as shown in Figs. 24 and 25, parallel connection of the resistor element 61 to the first control signal line 4 (that is, one end of the resistor element 61 is connected to the first control signal line 4 and the other end thereof is opened) is also effective in prevention of generation of resonance.

(FOURTH EMBODIMENT)

Figs. 26 and 27 are views showing a constitution of a phase shifter according to a fourth embodiment of the present invention. Fig. 26 is a circuit diagram and Fig. 27 is a plan view. In these figures, the same elements as those in Figs. 4 and 5 are designated by the same reference numerals and an explanation of the elements are suitably omitted.

The phase shifter shown in Fig. 26 is constituted by connecting the cantilevers 11a, 11b of the phase shifter shown in Fig. 4 to a grounding 5a via the stubs 3a, 3b and a fourth control signal line 4a. In this manner, the cantilevers 11a, 11b are grounded, whereby electric charges generated by electrostatic induction can be rapidly charged into the cantilevers 11a, 11b when application of voltage to the stubs 2a, 2b is started. On the other hand, when application of voltage is stopped, the electric charges accumulated can be rapidly discharged. Accordingly, the micro-machine switch is made stable in switching action and increased in switching speed. Thereby, the phase shifter can be rapidly and surely switched over in phase-shifting amount. In addition, the same effect can be also obtained when grounding is given with the fourth control signal line 4a connected to the main line 1 of the phase shifter shown in Fig. 12.

(FIFTH EMBODIMENT)

Fig. 28 is a circuit diagram showing a constitution of a phase shifter according to a fifth embodiment of the present invention. In Fig. 28, the same elements as those in Figs. 14 and 26 are designated by the same reference numerals and an explanation of the elements are suitably omitted.

The phase shifter shown in Fig. 28 is constituted by connecting the first high-frequency signal blocking unit 6 to the first control signal line 4 of the phase shifter shown in Fig. 26 and connecting a the second high-frequency signal blocking unit 6a to the fourth control signal line 4a. Here, the second high-frequency signal blocking unit 6a acts to block passage of the high-frequency signal RF same as the first high-frequency signal blocking unit 6.

Thus since the first and second high-frequency signal blocking units 6, 6a, respectively, are connected to the first and fourth control signal lines 4, 4a, leak of the high-frequency signal RF via the first and fourth

control signal lines 4, 4a from the main line 1 and the stubs 3a, 3b can be prevented. Thereby, it becomes possible to reduce insertion loss of and improve the high-frequency characteristics of the phase shifter. The filters 30, 40, 50 and the resistor element 61 can be used for the first high-frequency signal blocking 6 as the second high-frequency signal blocking unit 6a.

In particular, when both the first and second high-frequency signal blocking units 6, 6a are constructed in the same manner as the filter 40, they can be made simple in construction. Figs. 29 and 30 are views showing a constitution of a phase shifter when the first and second high-frequency signal blocking units 6, 6a are constructed in the same manner as the filter 40, Fig. 29 being a circuit diagram, and Fig. 30 being a plan view.

As shown in Fig. 30, the phase shifter can be constructed only by connecting the stubs 3a, 3b, shown in Fig. 18, to the earth electrode 43a by means of a high-impedance $\lambda/4$ line 41a. Here, the high-impedance $\lambda/4$ line 41a has the same construction as the high-impedance $\lambda/4$ line 41, in which the stub 2a is connected to the electrode 44. However, the phase shifter is designed so that the high-impedance $\lambda/4$ line 41a is constructed to have two branches in Fig. 30. In this case, an electric length between a connection to the earth electrode 43a and a connection to the stub 3a becomes $\lambda/4$, and an electric length between a connection to the earth electrode 43a and a connection to the stub 3b becomes $\lambda/4$.

In Fig. 29, the first high-frequency signal blocking unit 6 is composed of the high-impedance $\lambda/4$ line (first high-impedance line) 41, the capacitor 42, and the grounding 43. Also, the second high-frequency signal blocking unit 6a is constituted by connecting the high-impedance $\lambda/4$ line (the second high-impedance line) 41a to the grounding 43. In this manner, the phase shifter can be made small in size as a whole because

the micro-machine switch can be made small in size by sharing constituent parts between the first and second high-frequency signal blocking units 6, 6a. In addition, the first and second high-frequency signal blocking units 6, 6a may be constructed in the same or different manner.

(SIXTH EMBODIMENT)

Fig. 31 is a circuit diagram showing a constitution of a phase shifter according to a sixth embodiment of the present invention. In Fig. 31, the same elements as those in Fig. 4 are designated by the same reference numerals and an explanation of the elements are suitably omitted. The phase shifter shown in Fig. 31 is constructed such that the constant-voltage power source 5b is connected through a fourth control signal line 4a to the stubs 3a, 3b shown in Fig. 4.

Output voltage of the constant-voltage power source 5b is of reverse polarity to that of the control signal S outputted from the control device 5. More specifically, if the control signal S is composed of ON/OFF of positive voltage, the constant-voltage power source 5b outputs negative constant voltage. However, because the cantilevers 11a, 11b must act on the basis of the control signal S, the output voltage of the constant-voltage power source 5b is set to one in such a degree that only it does not cause the cantilevers 11a, 11b to act. For the cantilevers 11a, 11b designed to be actuated by the control signal S of 40 V in Fig. 4, output voltage of the constant-voltage power source 5b is set to, for example, -20V.

The cantilevers 11a, 11b are both formed at undersides thereof with the insulating film 14, and the stubs 3a, 3b are both opened at tip ends thereof. Accordingly, constant voltage applied to the stubs 3a, 3b is maintained in voltage value. In addition, the opened tip ends of the stubs 3a, 3b carry out the function of a third insulating unit described later.

In this manner, if a predetermined voltage is beforehand applied to the cantilevers 11a, 11b through the stubs 3a, 3b, the control signal S can be reduced in level of voltage. With the above-mentioned example, the cantilevers 11a, 11b can be made to act by application of ON/OFF signals of 20V to the line 1b as the control signal S.

When a high voltage is applied as the control signal S, surge generates and noises based on high-speed change in voltage become noticeable in some cases. However, with the micro-machine switch shown in Fig. 31, the control signal S can be made low in voltage, so that it is possible to solve such problems.

To obtain the same effect in the phase shifter shown in Figs. 12 and 13, it is necessary to specifically provide a third insulating section for keeping a voltage value for the constant voltage, together with the insulating film 14 formed on each of the cantilevers 11a, 11b. Such third insulating section can be constituted by forming, for example, the capacitors 15a, 15b shown in Fig. 4 in the same position on the main line 1. Alternatively, a coupling condenser contained in other microwave circuits connected to the main line 1 may be used as the third insulating section.

Fig. 32 is a circuit diagram illustrating a modified configuration of the phase shifter shown in Fig. 31. With a phase shifter shown in Fig. 32, the first and second high-frequency signal blocking units 6, 6a, respectively, are connected to the first and fourth control signal lines 4, 4a. The first and second high-frequency signal blocking units 6, 6a act to block passage of the high-frequency signal RF, and are constituted in the same manner as the phase shifter shown in Fig. 28. Connection of the first and second high-frequency signal blocking units 6, 6a eliminates an increased insertion loss of the phase shifter and degradation of the high-frequency characteristics of the phase shifter.

(SEVENTH EMBODIMENT)

Fig. 33 is a plan view showing a constitution of a phase shifter according to a seventh embodiment of the present invention. In Fig. 33, the same elements as those in Fig. 4 are designated by the same reference numerals and hence an explanation of the elements are suitably omitted. The phase shifter shown in Fig. 33 is a low deadline type phase shifter different from the type of the phase shifter shown in Fig. 4. These both phase shifters are different in constitution from each other in the following point. The phase shifter shown in Fig. 4 performs switching of connection/opening between the stubs 2a, 2b and the stubs 3a, 3b. In contrast, the phase shifter shown in Fig. 33 performs switching of connection/opening between the stubs 2a, 2b and an earth electrode 3c.

When the stubs 2a, 2b are connected to or opened from the earth electrode 3c in high-frequency fashion, susceptance on the side of the stubs 2a, 2b from the main line 1 changes. Accordingly, for the same reason as explained with respect to the phase shifter shown in Fig. 4, the high-frequency signal RF transmitting through the main line 1 can be switched over in phase-shifting amount by making the control signal S ON/OFF and thereby controlling high-frequency connection of the stubs 2a, 2b and the earth electrode 3c.

With the phase shifter shown in Fig. 33, the cantilevers 11a, 11b, respectively, may be fixedly mounted on the tip ends of the stubs 2a, 2b or on a periphery of the earth electrode 3c on the side of the stubs 2a, 2b. However, in the case of the former, tip ends (tip end of the arm 13) of the cantilevers 11a, 11b are made to freely come toward and away from the periphery of the earth electrode 3c on the side of the stubs 2a, 2b. On the other hand, in the case of the latter, the tip ends of the cantilevers 11a, 11b must freely come toward and away from the tip ends of the stubs 2a, 2b.

In addition, according to the present invention, the earth electrode 3c is defined as a distributed constant line having an electric potential of zero, and will be contained in the second distributed constant line. Also, the first high-frequency signal blocking unit 6 may be connected to the first control signal line 4.

(EIGHTH EMBODIMENT)

Several embodiments have been described in the case where the present invention'is applied to a low deadline type phase shifter. However, the present invention is not limited to such case but can be applied to other types of phase shifters, for example, switched-line type and reflecting type phase shifters, and the like.

An explanation will be given below to an embodiment, in which the present invention is applied to the switched-line type phase shifters. Fig. 34 is a plan view showing a constituent example of a phase shifter according to an eighth embodiment of the present invention. As shown in Fig. 34, a main line (first distributed constant line) 101 includes a cut part. The main line 101 is composed of two lines 101a, 101b with the cut part therebetween. And two switching lines (second distributed constant line) 106a, 106b are arranged with slight gaps between the both lines 101a, 101b and them. Such switching lines 106a, 106b have different electric lengths from each other.

Cantilever 111a, 111b, 111c, 111d, respectively, are arranged at four gaps between the lines 101a, 101b and the switching lines 106a, 106b. More concretely, the cantilever 111a is arranged between the line 101a and the switching line 106a, and the cantilever 111b is arranged between the line 101b and the switching line 106a. Also, the cantilever 111c is arranged between the line 101a and the switching line 106b, and the cantilever 111d is arranged between the line 101b and the switching line 106b.

These cantilevers 111a to 111d have the same construction as that of the cantilever 11a shown in Fig. 4. The cantilevers 111a, 111b, respectively, among the cantilevers are fixedly mounted on both ends of the switching line 106a, and tip ends (tip end of the arm 13) of the cantilevers 111a, 111b, respectively, are made to come toward and away from respective ends of the lines 101a, 101b. However, the cantilevers 111a, 111b, respectively, may be fixedly mounted on respective ends of the lines 101a, 101b, and tip ends (tip end of the arm 13) of the cantilevers 111a, 111b, respectively, may be made to come toward and away from both ends of the switching line 106a. Relationships among the cantilevers 111c, 111d, the lines 101a, 101b, and the switching lines 106a, 106b are the same as that described above.

A second control signal line 104a is connected to the switching line 106a so that a control signal (second control signal) S is applied to the switching line through the second control signal line 104a. A third control signal line 104b is connected to the switching line 106b so that a control signal (third control signal) $\overline{S}$ is applied to the switching line via the third control signal line 104b. A first control signal line is composed of the second and third control signal lines 104a, 104b.

The control signals S, $\overline{S}$ are two signals to be complementary to each other, and comprise signals composed of change of voltage Vcc and 0. Here, 0 electric potential indicates a ground potential, and Vcc indicates voltage other than 0.

Meanwhile, control signal lines 104c, 104d, respectively, are connected to the lines 101a, 101b, which constitute the main line 101. A constant bias is applied to the lines 101a, 101b via such control signal lines 104c, 104d. The constant bias is desirably one (in this case, Vcc or 0) of two states of the control signals S, $\overline{S}$. In Fig. 34, ground potential is given as the constant bias.

In addition, the constant bias may not be strictly identical to one voltage of the two states of the control signals S, $\overline{S}$, but are allowable in a range, in which the cantilevers 111a to 111d surely act in accordance with change of state of the control signals S, $\overline{S}$.

Also, although not shown, insulating films, respectively, are formed as a first insulating portion on undersides of tip ends of the cantilevers 111a to 111d (or 111C, 111d) as in the phase shifter shown in Fig. 4. However, one of two insulating films corresponding to the two cantilevers 111a, 111b provided on the same switching line 106a (or 106b) functions as a second insulating portion. A voltage value applied to the switching lines 106a, 106b, respectively, is kept by such insulating portions.

An explanation will be then given to an operation of the phase shifter shown in Fig. 34. When the control signals S, $\overline{S}$ are not applied to the both switching lines 106a, 106b (when 0 V), the switching lines 106a, 106b are not connected to the lines 101a, 101b in high-frequency fashion since the tip ends of the cantilevers 111a to 111d are spaced away from ends of the lines 101a, 101b.

In this state, it is assumed that the voltage Vcc is applied to the switching line 106a via the second control signal line 104a and the ground potential is imparted to the switching line 106b via the third control signal line 104b. Since the lines 101a, 101b are both given the ground potential, the tip ends of the cantilevers 111a, 111b, respectively, are attracted by electrostatic forces generated between them and the ends of the lines 101a, 101b to contact with the ends of the lines 101a, 101b. Thereby, the switching line 106a is connected to the lines 101a, 101b in high-frequency fashion to short-circuit the cut part of the main line 101.

Meanwhile, since the switching line 106b is at the same electric potential as that of the lines 101a, 101b, the tip ends of the cantilevers 111c, 111d are not put in contact with the ends of the lines 101a, 101b, and

so the switching lines 106a, 106b are not connected to the lines 101a, 101b in high-frequency fashion.

Subsequently, it is assumed that the ground potential is applied to the switching line 106a via the second control signal line 104a and the voltage Vcc is imparted to the switching line 106b via the third control signal line 104b. When application of the voltage Vcc to the switching line 106a is stopped, electrostatic forces between the tip ends of the cantilevers 111a, 111b and the ends of the lines 101a, 101b disappear. Therefore, the cantilevers 111a, 111b return to their original configurations, and so high-frequency connection between the switching line 106a and the lines 101a, 101b is released.

Meanwhile, the tip ends of the cantilevers 111c, 111d are attracted by electrostatic forces generated between them and the ends of the lines 101a, 101b to contact with the ends of the lines 101a, 101b. Thereby, the switching line 106b short-circuits, in place of the switching line 106a, the cut part of the main line 101 in high-frequency fashion.

In this manner, the control signals S, $\overline{S}$ are used to enable switch the switching lines 106a, 106b, which function to short-circuit the cut part of the main line 101. As described above, because the switching lines 106a, 106b have different electric lengths, an effective electric length between the lines 101a, 101b can be changed by switching the switching lines 106a, 106b, which function to short-circuit the cut part of the main line 101. Accordingly, the high-frequency signal RF transmitting through the main line 1 can be switched over in phase-shifting amount.

Fig. 35 is a plan view showing another constituent example of the phase shifter according to the eighth embodiment of the present invention. With the phase shifter shown in Fig. 35, a constant bias is applied to the switching lines 106a, 106b, and the control signal S is applied to the lines 101a, 101b, which constitute the main line 101. This makes the above-

mentioned phase shifter different from the phase shifter shown in Fig. 34. More specifically, as shown in Fig. 35, first control signal lines 104e, 104f, respectively, are connected to the lines 101a, 101b, and the control signal (first control signal) S is applied via the first control signal lines 104e, 104f. The control signal S is one composed of change of voltage Vcc and 0.

A control signal line 104g is connected to the switching line 106a, and the voltage Vcc is applied via the control signal line 104g. Also, a control signal line 104h is connected to the switching line 106b, and ground potential is given via the control signal line 104h.

The constant biases given to the switching lines 106a, 106b are desirably respective voltages (in this case, Vcc or 0) of two states of the control signal S. However, these constant biases suffice to be constant voltages equivalent to respective voltages value of two states of the control signal S, and are allowable in a range, in which the cantilevers 111a to 111d surely act in accordance with change of state of the control signal S.

Also, the lines 101a, 101b, which constitute the main line 101, respectively, are formed with capacitors 115a, 115b. The capacitors 115a, 115b are formed in the same manner as the capacitors 15a, 15b shown in Fig. 4. These two capacitors 115a, 115b constitute a second insulating portion.

The above-mentioned first control signal lines 104e, 104f, respectively, are connected between the ends of the lines 101a, 101b and the capacitors 115a, 115b. Accordingly, voltage value of the control signal S applied via the first control signal lines 104e, 104f is kept by insulating films (not shown) provided every the capacitors 115a, 115b and the cantilevers 111a to 111d.

With the phase shifter constructed in this manner, when the voltage Vcc is applied to the lines 101a, 101b as the control signal S, the switching

line 106b is connected to the lines 101a, 101b in high-frequency fashion. Meanwhile, when the ground potential is applied as the control signal S, the switching line 106a is connected to the lines 101a, 101b in high-frequency fashion. Accordingly, the high-frequency signal RF transmitting through the main line 101 can be switched over in phase-shifting amount since the switching lines 106a, 106b, which function to short-circuit the cut part of the main line 101, are switched over by the control signal S.

In addition, in the phase shifter shown in Figs. 34 and 35, leak of the high-frequency signal RF transmitting through the main line 101 can be prevented by connecting the first high-frequency signal blocking unit 6 to the control signal lines 104a, 104b, 104e, 104f and connecting the second high-frequency signal blocking unit 6a to the control signal lines 104c, 104d, 104g, 104h.

(NINTH EMBODIMENT)

The above-mentioned phase shifters according to the first to eighth embodiments can realize a digital phase shifter of a single bit. A digital phase shifter of two bits or more can be constituted by cascade-connecting these phase shifters having different phase-shifting amounts from each other.

Fig. 36 is a plan view showing a constituent example, in which two phase shifters are cascade-connected to each other. In Fig. 36, the same elements as those in Figs. 15, 16 and 28 are designated by the same reference numerals and an explanation of the elements are suitably omitted.

Phase-shifters 19-1, 19-2 cascade-connected shown in Fig. 36 present constituent examples of the phase shifter shown in Fig. 28, and the filter 30 shown in Figs. 15 and 16 is applied as the first and second high-frequency signal blocking units 6, 6a. However, the phase shifters

19-1, 19-2 are different in phase-shifting amount from each other.

The low-impedance λ/4 line 32 to constitute the filter 30 needs a comparatively large area. Hereupon, as shown in Fig. 36, for the filter 30 as the second high-frequency signal blocking unit 6a, the respective phase shifters 19-1, 19-2 use a single low-impedance λ/4 line 32a in common. Thereby, it becomes possible to make the second high-frequency signal blocking unit 6a constituted by the filter 30 small in size. In addition, the reference numerals 31a-1, 31a-2 designate high-impedance λ/4 lines for the phase shifters 19-1, 19-2.

With the filter 30 as the first high-frequency signal blocking unit 6, a low-impedance λ/4 line 32-1 of the phase shifter 19-1 and a low-impedance λ/4 line 32-2 of the phase shifter 19-2 are multi-layered to interpose between the low-impedance λ/4 lines 32-1, 32-2 an insulating film 35 made of SiO_2 or the like. Thereby, it is possible to reduce an area occupied by the two low-impedance λ/4 lines 32-1, 32-2. Also, since the respective low-impedance λ/4 lines 32-1, 32-2 are insulated in DC or low frequency fashion, control signals S1, S2 given to the phase shifters 19-1, 19-2 will not get interfered with each other.

In the case of manufacturing the phase shifter shown in Fig. 36, referring to Figs. 10(A) to 10(E) and Figs. 11(A) and 11(D), it is possible in the manufacture step (Fig. 10C) of the line 1b and the stubs 2a, 2b, 3a, 3b or the like to simultaneously manufacture a high-impedance λ/4 line 31-1, the low-impedance λ/4 line 32-1 and a first control signal line 4-1 in the phase shifter 19-1. An insulating film 35 can be manufactured simultaneously in the manufacture step (Fig. 11B) of the insulating films 14, 16a, and 16b. It is possible in the manufacture step (Fig. 11C) of the lines 1a, 1c and the cantilevers 11a, 11b to simultaneously manufacture a high-impedance λ/4 line 31-2, the low-impedance λ/4 line 32-2 and a first control signal line 4-2 in the phase shifter 19-2. In this manner, the phase

shifter shown in Fig. 36 can be manufactured with the same number of steps as in the phase shifter shown in Fig. 4.

Fig. 37 is a plan view showing another constituent example of two phase-shifters cascade-connected. With phase shifters 19-3, 19-4 cascade-connected in Fig. 37, the control signals S1, S2 are applied to the stubs 3a, 3b as with the phase shifter shown in Figs. 12 and 13. With this type of phase shifters, the low-impedance $\lambda/4$ lines 32-1, 32-2 can be multi-layered to attain miniaturization. In addition, the reference numeral 31a designates a high-impedance $\lambda/4$ line.

(TENTH EMBODIMENT)

The phase shifter according to the present invention may be formed on the substrate 10 together with other wiring. With the phase shifter according to the present invention, the microwave circuit (or millimeter wave circuit) may be formed by processing a part or all of the constitution of the phase shifter into chips and loading and mounting the same on the substrate 10. Here, chip processing means a processing, in which a multiplicity of unit circuits are formed together on another substrate with a semiconductor processing and cut every unit circuit, and loaded and mounted on the substrate.

Figs. 38 and 39 are plan views showing an arrangement, in which a phase shifter having been subjected to the chip processing is mounted on the substrate 10 to complete the phase shifter shown in Figs. 15 and 16. In Fig. 38, the line 1b, which is a part of the main line 1, the stubs 2a, 2b, 3a, 3b, the cantilevers 11a, 11b, and the capacitors 15a, 15b are subjected to the chip processing to form a chip 71. Meanwhile, the lines 1a, 1c, which is another part of the main line 1, the high-impedance $\lambda/4$ line 31, the low-impedance $\lambda/4$ line 32, and the first control signal line 4 have been beforehand laid out on the substrate 10. A function equivalent to that of the phase shifter shown in Figs. 15 and 16 can be realized by

mounting the chip 71 on the substrate 10.

Also, in Fig. 39, the chip processing is carried out on ends 2aa, 3aa of the stubs 2a, 3a and the cantilever 11a to form a chip 72a, and the chip processing is carried out on ends 2bb, 3bb of the stubs 2b, 3b and the cantilever 11b to form a chip 72b.

Meanwhile, the lines 1a to 1c, which constitute the main line 1, portions of the stubs 2a, 2b, 3a, 3b except the ends 2aa, 2bb, 3aa, 3bb thereof, the high-impedance $\lambda/4$ line 31, the low-impedance $\lambda/4$ line 32, and the first control signal line 4 have been beforehand laid out on the substrate 10. A function equivalent to that of the phase shifter shown in Figs. 15 and 16 can be realized by mounting the chip 72a, 72b and chip condensers 73a, 73b as the capacitors 15a, 15b on the substrate 10.

Examination of defects on the chips 71, 72a, 72b can be implemented separately by carrying out the chip processing on the phase shifter shown in Figs. 38 and 39. Thereby, there is produced an advantage that whole circuits, for which the phase shifter is used, can be enhanced in yield.

(ELEVENTH EMBODIMENT)

With phase shifter shown in Fig. 4, the insulating films 14 and 14a interposed between the underside of the tip end of the arm 13 and the top surface of the tip end of the stub 2a are used as the first insulating section for capacitive coupling of the stubs 2a and the stub 3a. However, the first insulating section can be constituted without the use of the insulating films 14 and 14a.

Fig. 40 is a plan view showing another constituent example of the first insulating section. Further, Figs. 41(A) and 41(B) are cross sectional views showing the first insulating section when OFF, Fig. 41(A) being a cross sectional view taken along the line A-A' in Fig. 40, and Fig. 41(B) being a cross sectional view taken along the line B-B' in Fig. 40. Also,

Figs. 42(A) and 42(B) are cross sectional views showing the first insulating section when ON, Fig. 42(A) being a cross sectional view taken along the line A-A' in Fig. 40, and Fig. 42(B) being a cross sectional view taken along the line B-B' in Fig. 40.

As shown in Fig. 40, projections 84a, 84b, respectively, are arranged on and separated from both sides of the end of the stub 2a. As shown in Figs. 41(A) and 41(B), the projections 84a, 84b are formed to have a slightly greater (higher) thickness than that of the stub 2a. The projections 84a, 84b may be formed from any one of dielectrics, semiconductors, and conductors.

Meanwhile, a post 82 is formed on the end of the stub 3a, and a base portion of an arm 83 is fixed to a top surface of the post 82. The arm 83 extends from the top surface of the post 82 to bridge across a gap and extends to above the end of the stub 2a. However, the arm 83 is larger in width at a tip end thereof than at the base portion thereof so that the tip end of the arm 83 face both of the projections 84a, 84b as shown in Fig. 40.

With such arrangement, when attractive forces based on the control signal S are generated between the stub 2a and the arm 83, the tip end of the arm 83 is drawn toward the stub 2a by the attractive forces. However, the projections 84a, 84b function as stoppers, so that displacement of the arm 83 is stopped at the top surfaces of the projections 84a, 84b as shown in Figs. 42(A) and 42(B). At this time, a thin air layer 84 is formed between the stub 2a and the arm 83. Presence of the air layer 84 causes the stub 2a and the arm 83 to be insulated from each other in DC or low frequency fashion, but the stub 2a and the arm 83 are coupled in high-frequency fashion because the air layer 84 is sufficiently small in thickness.

As described above, with the phase shifter according to the present invention, the cantilever of the micro-machine switch is fixedly mounted on the distributed constant line, and the first control signal is directly applied to the distributed constant line to have the same acting as a control electrode of the micro-machine switch. Thereby, posts, arms and upper and lower electrodes, which have been necessary in conventional micro-machine switches, are dispensed with, and hence it is possible to make a micro-machine switch small in size. Accordingly, a phase shifter, in which a micro-machine switch is used as a switching element, can be made small in size as a whole. Also, the micro-machine switch is simple in construction, and so phase shifters can be manufactured in the small number of processes.

Also, leak of the high-frequency signal to the first control signal line can be prevented by connecting to the first control signal line the first high-frequency signal blocking unit for blocking passage of the high-frequency signal. Accordingly, insertion loss of a micro-machine switch can be reduced. Also, a circuit, in which the phase shifter is used, can be improved in high-frequency characteristics since electromagnetic coupling of the first control signal line with other lines can be prevented.

Also, the fourth control signal line is connected to that one of the first and second distributed constant lines contained in the phase shifter, to which the first control signal is not applied, and charging and discharging of electric charges generated by electrostatic induction is effected through the fourth control signal line. Thereby, the micro-machine switch becomes stable in switching action and rapid in switching speed, so that the phase shifter can be surely and rapidly switched in phase-shifting amount.

Also, the fourth control signal line is connected to that one of the distributed constant lines, to which the first control signal is not applied,

and voltage of reverse polarity to that of the first control signal is applied, whereby voltage of the first control signal can be reduced in level to suppress generation of surge and noises.

In these cases, the second high-frequency signal blocking unit for blocking passage of the high-frequency signal is connected to the fourth control signal line to thereby enable preventing leak of the high-frequency signal to the fourth control signal line. Accordingly, problems such as an increase in insertion loss and degradation of the high-frequency characteristics will not be caused.

Also, in the case where the first and second high-frequency signal blocking units are constituted by a bias tee making use of capacitors, the constitution can be simplified by sharing of constituent parts.

INDUSTRIAL APPLICABILITY

Various embodiments of the phase shifter according to the present invention have been described above. The phase shifter according to the present invention can be used in, for example, phased-array antennas.